Mathematical modeling of fluid flow and substance transport in a cylindrical porous filter

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Abstract - In this article, a complex mathematical model is proposed, including fluid flow, substance transport, adsorption, and clogging processes in a cylindrical porous filter. The model is based on the Brinkman-Darcy approach, which presents the conservation of mass, radial and axial pulse equations, and the porosity-permeability relationship through the Kozeny-Carman formula. For pollutants in the liquid phase, the kinetics of convective-diffuse transport, bulk reactions, and adsorption are taken into account. The adsorption process was described using the LDF-kinetic model and the multicomponent Langmuir isotherm. A model of particle settlement on the surface of the filter layer and pore reduction over time (collation) is also introduced. In the presence of a membrane, permeate flow and salt transport are determined by hydraulic permeability, reflection coefficient, and cake resistance. The proposed model can be used to assess the efficiency of the filter, service life, and the quality of the outlet water.

Keywords: cylindrical filter, porous medium, Brinkman-Darcy equations, Kozeny-Carman formula, substance transport, adsorption, Langmuir isotherm, LDP kinetics, colmatation, membrane processes, water purification, mathematical modeling.

1 Introduction

One of the priority areas of modern environmental and engineering problems is the conservation of water resources, the effective removal of industrial and domestic pollutants, and ensuring the quality of drinking water. Porous filters (granular filtration systems, biofilters, membrane systems equipped with filter layers, etc.) are widely used in many industrial and utility applications of these problems. However, for a complete understanding of the actual behavior of filters, a